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October 10, 1991

U. S. Nuclear Regulatory Commission
ATTN: Document Control Desk
Washington, DC 20555

Subject: Catawba Nuclear Station, Unit 2
Docket No. 50-414
Special Report
Valid Failure of Diesel Generator 2A

Pursuant to Technical Specification 4.8.1.1.3 and 6.9.2, find attached a Special Report concerning the Unit 2 Diesel Generator A (D/G 2A) valid failure that occurred on September 11, 1991.

Very truly yours,

M. S. Tuckman

M. S. Tuckman

CRL/DG2A1009.91

Attachment

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Regional Administrator, Region II

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SPECIAL REPORT

CATAWBA NUCLEAR STATION

DIESEL GENERATOR 2A VALID FAILURE DURING OPERABILITY TESTING OF ENGINE

A valid failure (start # 665) of Diesel Generator (D/G) 2A occurred on Sept 11, 1991 at 1228 hours. The valid failure occurred during the Operability Test (PT/2/A/4350/02A) following minor corrective and preventative maintenance to one air start valve on the engine and other system air valves. During the Operability Test, jacket water and lube oil temperatures were observed to be rising. The engine tripped when the lube oil outlet temperature trip set point was reached. While the engine was coasting to a stop, a mild crankcase explosion occurred.

D/G 2A was a monthly operability test schedule at the time of this valid failure. There are now 2 valid failures in the past 20 valid starts, 2 valid failures in the past 50 valid starts and 4 valid failures in the past 100 valid starts for D/G 2A. D/G 2A is currently on a 7 day operability test schedule per Technical Specification 4.8.1.1.2 Table 4.8-1.

The 2A diesel generator was unavailable for 8 days.

Chronology

At 0505 on 9/10/91, the 2A emergency diesel was removed from service to perform scheduled minor corrective maintenance on one right bank starting air block valve, the air receiver tank drain valve and the starting air dryer controls. These maintenance activities had no bearing on the failure that occurred.

After the scheduled corrective maintenance, the engine was started (about 1130 9/11/91, start number 664) from the diesel room to run performance testing on the right bank air start block valves. The performance test ran for approximately 5 minutes at no load and was completed satisfactorily. A normal engine shutdown was performed.

The engine was restarted (about 1200, start 665) from the diesel room for the Operability Test. Following the start, the engine oil level was checked and found to be 87% (within normal range). During log taking, after 15 minutes at full load, the operators noticed that the Engine Cooling Water System (KD) and Lubricating Oil System (LD) temperatures were rising together. After 20 minutes, the high LD in and out and high KD temperature annunciators alarmed. One operator investigated the Plant Service Water System (RN) supply valve position to the KD/RN heat exchanger and found it correctly positioned open. As that operator returned to the control panel (about 28 minutes into the run) the engine tripped on high LD outlet temperature (200°F trip point). No abnormal sounds were heard as the engine began to slow. 15 to 30 seconds after the trip, as the engine rolled to a stop, an explosion was heard. The smoke appeared to the operators to be medium gray rather than black and came from the left bank side of the engine through the crankcase pressure relief valves. The second operator had called the shift supervisor to report the high temperature problem and was discussing it with him when the explosion took place. The operators noted that there was no fire following the noise and then quickly left the room. The fire brigade was called and responded. The carbon dioxide fire protection system remained active but did not actuate because no demand was placed on the system.

The room was ventilated for about 20 minutes. The shift manager, the operators, Maintenance Engineering Services (MES) reps and Maintenance technicians then entered the room. An oil film was found on the left side of the engine, on the heat exchangers and on the floor.

An MES rep contacted the General Office, Nuclear Production Department and Catawba Design Engineering for assistance. An MES rep contacted the diesel vendor, discussed the problem and requested immediate technical support. That vendor support arrived at 0900 on Sept 12, 1991 and remained until the diesel generator was declared operable.

Investigations, Corrective and Subsequent Actions

In conjunction with the mechanical investigation, Instrument and Electrical (IAE) technicians inspected and tested the annunciator and shutdown devices to verify their set points, functions, and integrity. All instruments tested satisfactorily.

The engine side covers were removed for an internal inspection. Jacket water was found to be flowing from around the 1 left (1L) cylinder liner past the lower seals into the crankcase (LD system). The lube oil recirculation pump and heaters were turned off. Steps were taken to drain KD via normal drain paths to stop the flow of water into the crankcase. An estimated 100 gallons of water entered the crankcase and mixed with the oil.

Samples of oil were taken from the LD heat exchanger and from the in service lube oil filter to determine if water contamination was present throughout the system. Sample results indicated that there was no water in the system. The water was limited to the crankcase and sump tank.

While draining the LD system, the 1L cylinder head and piston were removed because of the discoloration and the liner seal leakage. The 1L liner had areas, especially near the lower end, that were blue, thus indicating overheating. The liner was removed and inspected further. The liner seal O-ring appeared to have been "burned" in the area adjacent to the overheated blue area of the liner bore. All of the 1L liner O-ring had carburizing to some extent. Areas on the O-ring immediately adjacent to the carburized areas showed no ill effects in that the O-ring material had not changed color and was still soft and pliable. The portions of the 1L liner O-ring that were not burnt were compared to new liner O-rings. No difference in resilience was evident. According to the O-ring manufacturer's literature, the maximum continuous operating temperature for a viton O-ring is 400 degrees Fahrenheit with tolerance for intermittent excursions to 600 degrees Fahrenheit with no detrimental effects to the O-ring's physical or chemical properties.

The 1L piston had signs of overheating and scuffing/scoring on the skirt. The piston ring contact surfaces were inspected under magnification and found to be heat checked with small regions of bluing, typical of running over the heated liner surface. The piston was replaced. Piston wrist pins, link pins and connecting rods were visually inspected and were not damaged. The connecting rod bearings, piston pin and link pin bushings were not damaged. The bearings, bushings pins, and journal were dimensionally inspected and were found to be satisfactory.

The 1R piston was removed with the 1L piston to better facilitate work on the 1L piston. The 1R piston did not show signs of overheating, scuffing, or unusual indications. The piston wrist pin moved freely and was not damaged. These parts were returned to service after cleaning. The 1R liner was removed for inspection. The liner O-ring were resilient and showed no evidence of heat damage when compared to new liner O-rings. The 1R liner had no unusual indications. The liner was replaced as a matter of convenience to reduce inspection time.

Inspections were made of the visible lower portion of all remaining cylinder liners. The injection nozzles were removed and a baroscope was used to inspect the upper end of the liners. The 7R cylinder had a scuff mark about 2.5" wide on the side nearest to cylinder 6R. The 7R cylinder head and piston assembly were removed for further inspection and honing of the cylinder liner. The piston skirt had indications of contact with the liner. The piston skirt was replaced and will be returned to the vendor for retinning. The 7R liner scuff was significantly less severe than that seen on the 1L liner and had no evidence of overheating. The scuff was removed by honing.

The inside of the crankcase was darkened from soot as a result of the mild explosion. A very light film of rust, possibly from the water contamination of the oil, had formed on portions of the cylinder liner bore adjacent to the piston pins. No other abnormal conditions were found in the crankcase. The #1 and #7 connecting rod bearings were found to be in good condition, were dimensional stable and exhibited no damage or abnormal wear.

The jacket water pump was inspected and found to be in good condition.

The thermostatic control valve, manufactured by AMOT Controls, was disassembled and the old elements removed and examined. Two of the four power elements had failed. One of the power elements was missing a 1 inch long piece of the stem housing retaining metal. This is a part of the base housing that is rolled over to clamp the valve stem and guide to the base housing thereby capturing the expansion medium making up the power element. The active medium was visible in this location in both failed elements. The 2 remaining power assemblies showed no visible damage or cracking on the rolled over edge. However, under magnification, one of the undamaged elements did show a tiny crack-like indication at the rolled edge. Unloaded dynamic tests performed on all 4 of the original power elements provided the following results: a) the 2 apparently undamaged elements met all manufacturer's static and active dimensional specifications, and b) the 2 damaged elements did not move from the retracted initial set position. All 4 of these elements were examined at the metallurgy lab to determine the root cause and/or failure mechanism of the power elements. The cause was determined to be slow growing intergranular stress corrosion cracking. The metallurgy report is available on request. New elements were obtained from Cooper/Enterprise and all four elements were replaced.

AMOT Controls stated that the power elements do not catastrophically fail unless they are overheated. The normal indication for a degraded power element is an upward trend in jacket water and lube oil temperatures (i.e. the temperatures are being controlled in a higher than normal range). Recognition of this higher than normal range should provide ample warning of diminishing temperature control.

Calculations of system heat load and required heat rejection for continued safe operation indicate that the AMOT thermostatic control valve did function, although at a reduced capacity. This is borne out in reviewing the continuous reading strip chart recorder which shows a gradual rise in temperature under sustained full load. This gradual rise in temperature was also seen in previous testing of damaged power elements conducted at this site.

Conversations with Senior Design and Technical Support Engineers of Energy Services Group, Cooper Industries, informs us that no failures have been reported concerning AMOT thermostatic control valves. Neighboring utilities, having the same configuration, had not experienced nor heard of an AMOT thermostatic control valve failures.

After engine reassembly, the cooling water (KD) system was filled, vented and hydrostatically tested to 15 psi to verify correct liner to block O-ring seating in all cylinders. This leak test was completed satisfactorily on all cylinders.

The lube oil tank and piping, including all filters and strainers, were drained and thoroughly cleaned. The system was then flushed with new oil and cleaned again. New filters and oil (Mobilgard 412) were then installed.

Throughout the incident, several management meetings were conducted that included the site NRC representative and the Cooper/Enterprise vendor representative. Discussions included findings, conditions, effects, possible causes, and actions and alternate actions to complete appropriate inspections and restoration of the diesel generator.

The engine was started and run per the modified breakin run procedure. Additional barring and air rolling steps and inspections were added before actually starting the diesel generator. The first start was a one minute, unloaded run followed by visual inspection of the interior surfaces. A series of longer, unloaded runs was made with each run followed by an inspection. The last two runs consisted of a 1 hour, 1100 kW loaded run followed by a visual inspection and then an 8 hour minimum, continuous, various load run prescribed by the vendor instruction manual and approved by the on site diesel representative. At shutdown, the crankcase doors were removed and a visual inspection of the interior surfaces was again preformed. No abnormal temperatures or conditions were observed during any part of the restoration process.

Tests required by Performance were satisfactorily conducted and the diesel generator turned over to Operations for the performance of the Operability Test. The Operability Test was satisfactorily completed and the diesel generator was declared operable.

Conclusions

Heat is conducted from the engine components to the lube oil system (LD) and the jacket water system (KD). LD heat is rejected to KD via the LD/KD heat exchanger. KD is cooled via the RN/KD heat exchanger. These heat exchangers are mounted on the engine room wall facing the left bank of the engine. The AMOT valve diverts KD system flow from the RN/KD heat exchanger when KD temperatures are low. The AMOT works proportionally to control KD temperature at about 165°F by biasing the flow between the RN/KD heat exchanger and the lube oil cooler.

The OAC computer plot showed that the RN flow through the RN/KD heat exchanger was between 1450 to 1480 gpm (considered normal). The jacket water pressure could not be determined. However, the low pressure annunciator did not alarm. A review of the strip chart recorder shows that the LD temperature peaked at about 210°F.

The AMOT valve only partially opened from the bypass position which provided insufficient cooling because of the failed power elements. The power elements were those originally provided with the engine in 1979. Power elements have a 15 year shelf life. Plans had been made to replace the Unit 2 power elements after finding degraded elements on Unit 1 in May 1991. Orders for new power elements had been placed with earliest possible deliveries scheduled for October 1991. Work Requests 4438MES and 4439MES had been written to inspect and replace both D/G 2A and 2B thermostatic control valve power elements in the upcoming Unit 2 Outage (2EOC4) in October 1991.

The AMOT valve failure allowed the KD and LD temperatures to slowly rise above normal operating temperatures. With the engine loaded to 100%, oil and water temperatures rose to around 200°F. Because lube oil temperature leads or is higher than jacket water temperature, the diesel generator shutdown on high temperature lube oil. At these elevated temperatures, the oil emits an increased amount of vapor. The elevated temperatures also affected the clearances between the moving parts and reduced the oil's strength and lubricating qualities. This action is believed to have initiated the 1L cylinder scuffing. The 1L cylinder bore diameter was found to be slightly smaller than the other liners measured. 1L's slightly reduced running clearance at the elevated temperatures seen in this incident explains why 1L was the first cylinder to see scuffing damage. That damage caused additional localized friction heating and scuffing, raising the 1L cylinder temperature high enough to cause general and localized bluing of the liner. (Bluing indicates the metal was heated to about 600°F to 650°F). The liner seals behind most of the blue areas were burned from the scuffing heat allowing them to start leaking. The localized high temperature of 1L cylinder was high enough to ignite the overheated crankcase vapors. The ignition of the oil vapors caused the rapid pressure increase in the crankcase. The left side of the engine is equipped with crank case pressure relief valves which are spring loaded openings to vent the gasses associated with crankcase explosions. They also prevent the entry of fresh air into the crankcase which could cause a secondary explosion and fire. The crankcase relief valves functioned as designed in this situation.

This engine has operated reliably for more than 750 hours with this liner under normal operating conditions.

The root cause of the 2A diesel generator failure is a failure of the AMOT thermostatic control valve due to slow growing intergranular stress corrosion cracking in the rolled area of the power elements. The cracking caused small openings that allowed the thermally active medium of the power element to be extruded out of its confines. This loss of thermally active medium directly effected the actuating rod travel, i.e. valve stroke or opening. Thus, the operating temperatures rose gradually over a long period of time. This active element loss will continued until the elements had so much damage that lube oil and water temperatures could not be automatically maintained without operator assistance. Operator assistance means removing the heat load by unloading the diesel generator, or overriding the thermostatic control valve, or shutting down the diesel generator.

An investigation into similarities between this AMOT thermostatic control valve power element failure and the one that occurred on D/G 1A on April 25, 1991 is continuing. A Supplemental Report will be submitted at the conclusion of this investigation.

Immediate Actions

1. Changed the AMOT power element replacement schedule to every 2 to 3 years to coincide with an alternate outage schedule as defined in the DRQR Appendix II Rev.

3. This time period was specified by a recent correspondence with Cooper Industries in which AMOT valve instructions were included.

2. Changed the AMOT power elements in the 2B diesel generator.

Planned Actions

1. Operations will review existing procedures to assure that they provide guidance for consistent and appropriate operator action for all alarm responses.

2. Further investigate the replacement of the engine oil with the synthetic that is used in Unit 1 engines. The synthetic offers increased film strength and greater stability at elevated temperatures.

3. Investigate possible enhancements to the current continuous reading strip chart recorder to improve printout readability. This would improve operator graphic information that would help the operator in selecting the most appropriate immediate action for the condition.

4. Submit a Supplemental Report containing the results of further investigations into AMOT thermostatic control valve power element failures.